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This report contains articles on the preparation of Introductory Physical Science (IPS) for commercial publication, objectives and content of the course, and the IPS leadership training program. Two articles discuss testing as a means of student evaluation, and statistics are presented to indicate student performance on IPS by grade level and scholastic ability. A series of short articles concerning IPS apparatus, the IPS paperback edition, and the IPS philosophy is presented. Two articles concern the development of Physical Science II. One is entitled, "The What and Why of Physical Science II," and includes the table of contents of the new course. The other article is entitled, "College Admissions and Physical Science II." Lists of colleges which will accept Physical Science II and IPS for admission credit are presented. An article concerning student attitudes toward Physical Science II and one concerning teacher attitudes complete the report. (BC)

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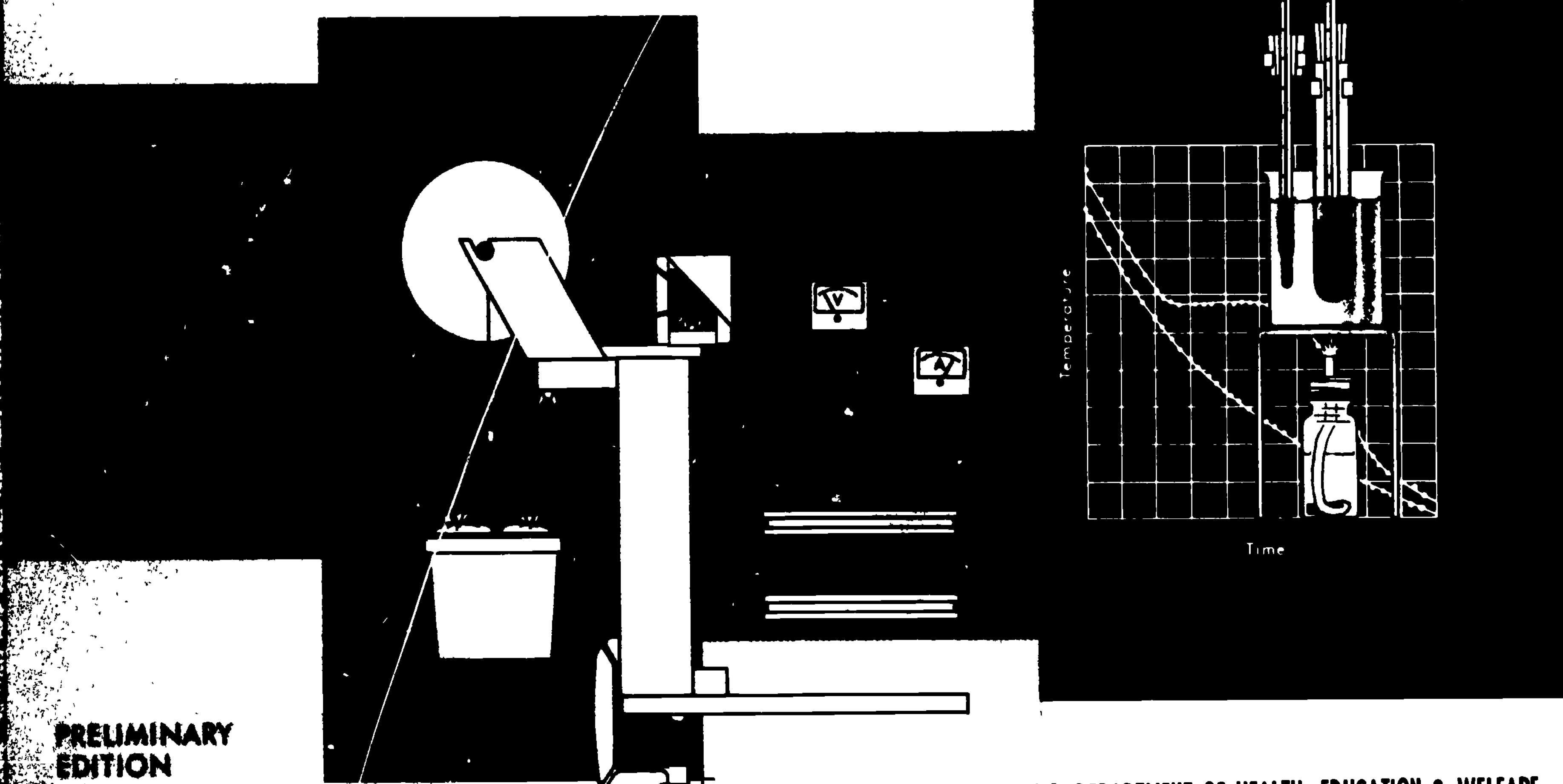
Introductory Physical Science

PHYSICAL SCIENCE II



PRELIMINARY EDITION

IPS GROUP
EDUCATION DEVELOPMENT CENTER

A Progress Report

For further information on Introductory Physical Science or Physical Science II, write to

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INTRODUCTORY PHYSICAL SCIENCE
Accent on Implementation

By URI HABER-SCHAIM
Director, IPS Group

The preparation of materials for the first commercial edition of IPS is now almost completed. Student text, Teacher's Guide, laboratory equipment, and one set of achievement tests are now available. Two additional sets of multiple-choice achievement tests and a booklet on laboratory tests will be published soon. The use of the course in the schools is rising rapidly and brings with it the problems of large-scale adoptions. It also focuses attention on remaining weak spots in science programs in secondary schools. It is not surprising, therefore, that the efforts of the IPS Group are now directed to assisting schools in the successful implementation of the IPS program and to creating a second-year course in physical science to follow it. This progress report deals with these two aspects of the Group's work.

From the beginning of the IPS program we have urged schools to try the course only with a teacher who has had the opportunity to study it in sufficient depth to understand its philosophy and to acquire the basic skills for teaching it. Several ways were available to teachers to get the necessary training. First of all, there were a number of summer institutes supported by the National Science Foundation. These were followed by NSF-supported inservice institutes and Cooperative College School Science programs and workshops supported and organized by state departments of education. Further opportunities for obtaining the needed training were later provided by local workshops directed by selected IPS teachers. The expenses of these workshops were met in some cases by the school systems themselves, and in others by the publisher of the IPS materials.

All these sources however, were not sufficient to meet the demand for trained IPS teachers. A new way had to be found to supply the training where it was most needed. An attempt in this direction was made last summer through the Leadership Conference. This is described in the article by Gerald Abegg.

One of the most noticeable discrepancies between what is being preached and what is being practiced in schools is in the field of testing. All science teachers agree that it is important to teach the students to think, to understand the basic principles of science, to apply their knowledge to new situations, etc. However, to produce tests which will be consistent with these aims is not a simple matter, and students very quickly discover what really counts when it comes to getting a good mark for their work. It was therefore imperative to provide guidance for the teachers to judge achievement in the IPS program. In this course the student engages in a large variety of activities which range from manual operations like assembling equipment, taking measurements, and plotting graphs to analyzing results, drawing conclusions, and solving problems. No single test can measure achievement in all these activities, and a teacher must use several yardsticks to justify his evaluation of a student's progress. A review of the IPS Group's work in these matters is given in the articles of John Dodge and Raymond Thompson.

Experimentation by the students plays a key role in the IPS course. This can give satisfaction or frustration, depending on the quality of the equipment used. Normally there is no stage in the release of apparatus which is equivalent to the proofreading of a book. Therefore we had to look for new ways of guaranteeing that the equipment which reaches the schools is up to standards, while at the same time encouraging competition among manufacturers and utilizing their knowhow in production and manufacturing. How we do this is described by James Walter.

One of the things I always found most bewildering is the common practice of schools providing books for the students for the duration of the school year only. From the junior high school up it seems reasonable that a book not worth keeping is not worth studying in the first place. To encourage school systems to let their students keep the IPS textbook the publisher was asked to make it available both in hardcover and in paperback format. Comments on how the paperback is being used are given by Edward A. Johnson, Robert T. Fitzgibbon, Arthur G. Suhr, and John N. Meade.

Objectives and Content of the Course*

By URI HABER-SCHAIM

There has been considerable progress in recent years in the teaching of physics, chemistry, and biology in the secondary schools. The Physical Science Study Committee course in physics, the Chemical Bond Approach and Chemical Education Material Study in chemistry, and the Biological Sciences Curriculum Study in biology are well known. But these courses do not exhaust the field of science instruction at the pre-university level. Some science is usually taught in grades 7, 8, and 9 in the junior high school, often in all three grades. By providing new course material for the last three years of high school, we increased the contrast between those years and grades 7, 8, and 9.

The question is: What can one do, or what should one do, to extend the gains achieved in the upper grades to the lower ones? What should be the content, what should be the emphasis, and what, primarily, should be the purpose of science instruction in those years? There are certainly more than one answer to these questions. Here we have confined our attention to a one-year course in physical science, aimed primarily at the ninth grade.

It is worth while to recall briefly the main questions which we asked at the very beginning of the PSSC physics course development. We asked: What is the objective of the course? What do we want to achieve? What is the purpose? What are the values we want to get across? From the answers to these questions we constructed an outline of what the content should be and how it should be taught. The chemists and biologists did likewise in planning their programs. In planning the present course for junior high school we had before us the work of PSSC in physics, of BSCS in biology, and of CBA and CHEMS in chemistry, so the matter of aims was not an entirely independent question any more.

The greatest handicap faced by science teachers in the new curricula is that most students in senior high school have no experience in observations, no basic laboratory skills, no knowledge of how to apply elementary mathematics to experimental results; they also lack the ability to correlate an abstract idea with a concrete situation. Often they have no idea of orders of magnitude, no feeling for approximation, no ability to judge what is important and what is not.

Often their earlier training has given students the idea that science is remote from real life and from anything they can do. The standard phrase in many textbooks is that "scientists have found such and such," and "scientists do so and so," and the student is requested just to memorize it. Science in many books means primarily vocabulary. All too often, important words are printed in heavy type and the student is asked to remember them. In science, however, words can have meaning only as they are associated with an action or an operation.

Students need time to digest knowledge. From the very first, PSSC physics teachers kept saying that if only we could get into the earlier grades some of the basic ideas and skills which are needed so badly in PSSC, it would make the

*Adapted from a lecture given at Florida State University, Tallahassee. Reprinted by request from an earlier progress report.

course much easier to teach and give the students much more time to digest the materials. And so, out of requests from teachers in the field came the call to start something to serve as a common foundation for the later courses in the senior high schools. This means not only a foundation of subject matter, but also an attitude of inquiry coupled with experimental and mathematical skills.

Physics and chemistry are elective subjects, and a fair fraction of the school population takes tenth grade biology as its last course in science; some students have no science at all in senior high school. Unfortunately, many can even get through college with no additional science, and will be ill equipped to understand a world dominated by the terminology and implications of science and technology. Therefore, our new course must also serve as a terminal course in physical science for many students, as well as provide a foundation for further work.

Thus we must have a program to serve two purposes: on the one hand to be a sound foundation for future physics, chemistry, and perhaps biology courses; and on the other hand to furnish sufficient nourishment in the essence, the spirit, and the substance of physical science to be a good terminal course for those who will not study physical science later on.

We believe that there are certain values and skills that can and should be taught in junior high school science. First, we want to give a feeling for the kind of human effort that is involved in the development of science. We want to put across the point that the root of all science is phenomena and that the names come later. We should like the student to get his information from the original source, from nature itself. This calls for real investigation in the laboratory. But science is not all laboratory work. We have to correlate and generalize our observations. We have to construct models or theories which can be manipulated logically and which will raise new questions. Later we do other experiments to seek the answers to these questions.

This poses many technical problems in constructing such a course. It is hard to design an experiment which, when handled by ten young fingers, will come out the way you think it should. Following a schematic drawing in a textbook is not enough.

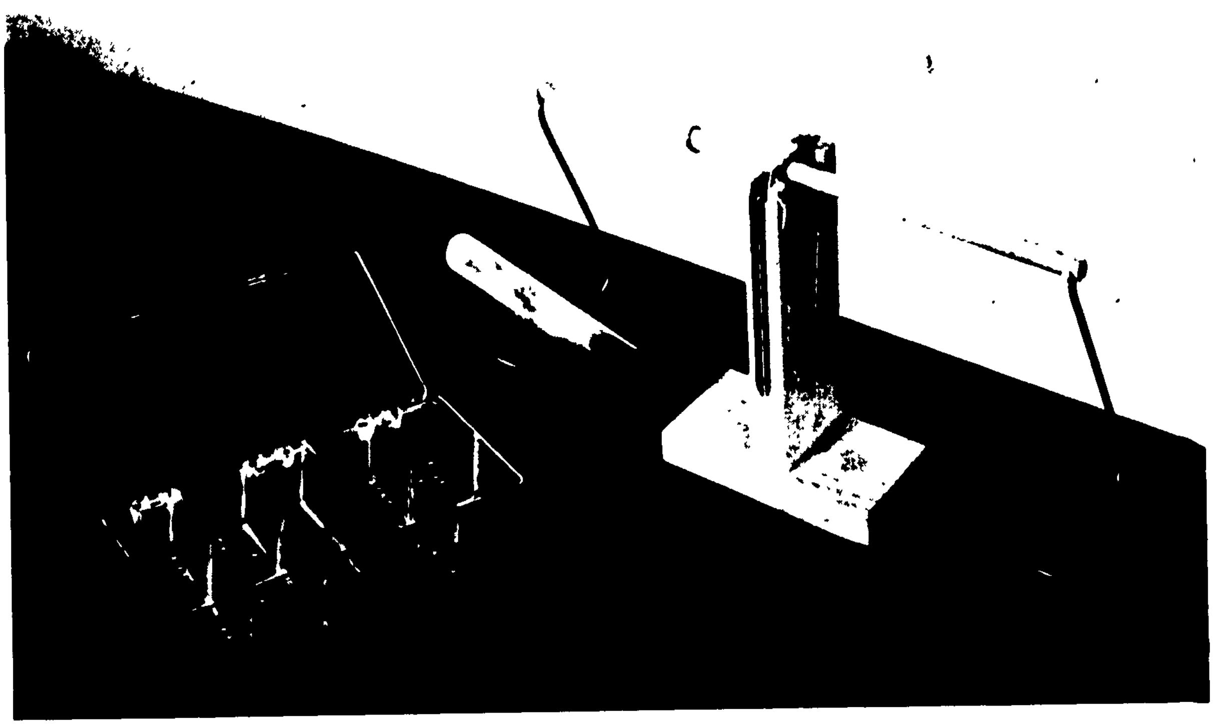
Time is always an important limiting factor in the laboratory, and this may make it hard to draw valid conclusions from the limited data available. This difficulty can often be relieved by combining the data of all the students and putting it on the board. Here is a good opportunity to teach the handling of errors. When students compare their measurements, they see the errors and learn how to decide which results are significantly different and which are within the experimental errors. We can save time by not asking all students to do exactly the same experiment. For example, in connection with the idea of boiling point, all the students boil water, but each uses a different quantity and some unknowingly get water with various amounts of salt dissolved in it. Each student gets a different graph of temperature versus time, and all of these are placed on the board. We thus have enough information to discuss whether the boiling point depends on the quantity of water or whether there are other significant differences.

Content of the Course

In selecting the topics, we used the same criteria as we did in the construction of the PSSC. That is, we asked: How much does the student benefit by learning this? How useful is it later in the development of the story? We feel that a topic that appears in our outline only once should not appear at all; it has no "mileage," and we can do very well without it.

No particular set of prerequisites was assumed in the students except some general familiarity with our technological society. In other words, we assumed that the students had seen common household instruments and objects. For example, we assumed they would know what a thermometer is, but there is a great difference between that and assuming that they had heard about atoms. The student can hold the thermometer in his hand and see the liquid rise when he puts his thumb on the bulb. The atom is another story; he has never seen one, and we must not rely on things with which he has no association or experience.

We have chosen as a central theme of this course the introductory study of matter. If we look around us we see a bewildering variety of matter; we can try to bring order into this seem-



The equal-arm balance designed for the IPS laboratory. Note the box containing bead weights in various amounts.

ing chaos by breaking up the many kinds of matter into simpler components, and then combining these components into a pattern. If we cannot build a pattern, then we can only catalogue things as a collector catalogues stamps.

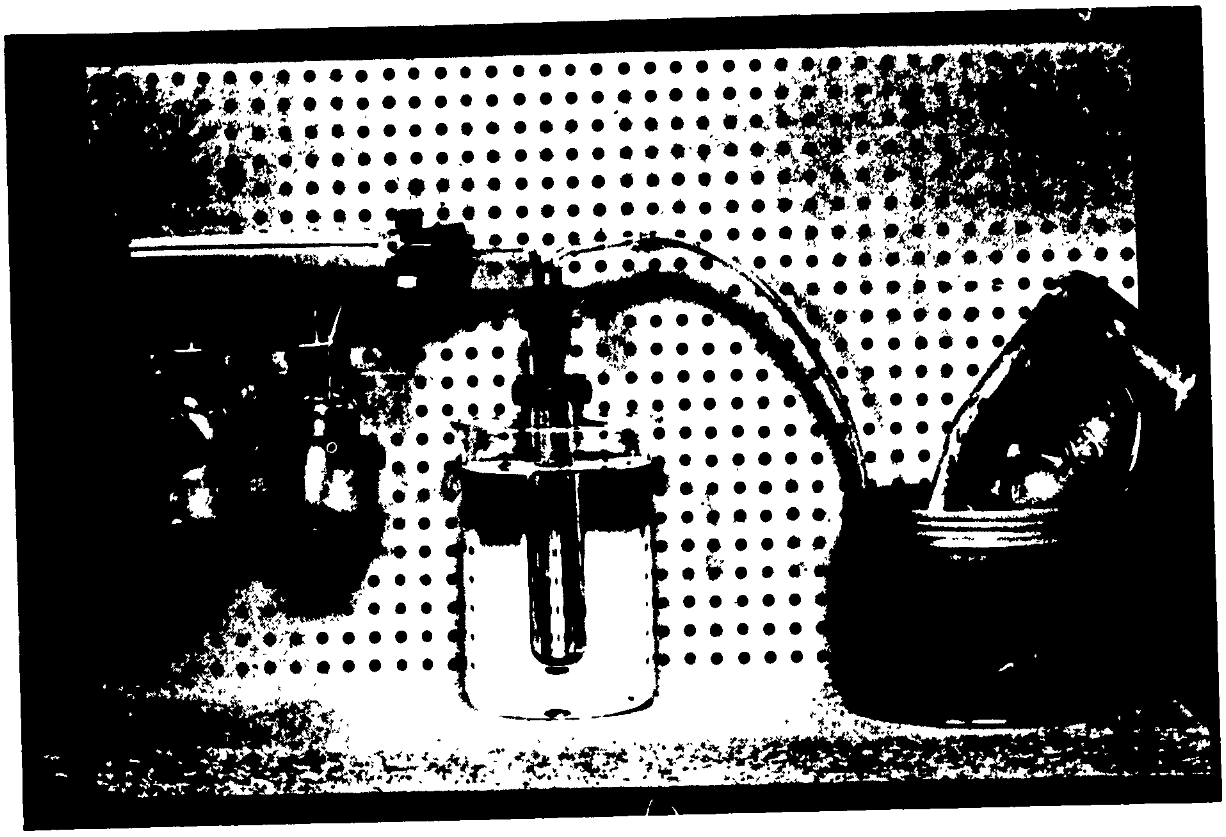
Characteristic Properties

Scientific inquiry begins when we do things on purpose instead of just compiling our experience as it comes. When we look outdoors, we see different kinds of leaves of different colors and different sizes; we see stones; we see trees. We know that these things are different, because we have touched them many times, held them in our hands, broken them. This is all fine, but then we meet up with two things which on first sight look the same. We ask: Are these two objects the same, or are they not? Then we have to do things to them deliberately in order to find out. To the person working in the field, it is obvious that you do the same thing to both, and you see whether they react the same. Yet, strangely enough, this basic concept — the idea of doing the same thing to two samples to see if they react the same way — is completely missing from most texts.

Perhaps even more fundamental than the idea of differences between substances is the idea of quantity. It is essential to be able to say "how much" without regard to what particular thing we have. How can we compare an amount of chalk with an amount of paper, and an amount of gas or air with an amount of water? The answer lies in the balance: we say that two amounts of matter are the same when they are in equilibrium on the equal-arm balance. We call this property "mass," without elaborating further. The next step is to look for properties which are independent of the amount and the shape and other conditions. We must show first that there are indeed such characteristic properties that do specify a substance as distinguished from other substances.

There is a large variety of characteristic properties to choose from, and we cannot discuss all of them; we choose those which can be used to separate substances from one another. Density is one: some things will float in water; others will sink. Solubility is another: some things will dissolve readily; others will not. Boiling point is another: one can separate substances by fractional distillation.

There is another consideration which influences the choice of characteristic properties; this is their usefulness in building a model or theory of matter. We need properties which can be combined to give us a unified picture of matter. In this context the similarity in the behavior of gases and the diversity in the behavior of liquids and solids is very significant.



Apparatus for collecting gas from the distillation of wood. The basic laboratory setup is a sheet of peg board supported by a heavy base; the smaller pieces of apparatus are held by clips bolted to the peg board. This makes an inexpensive and compact arrangement which can be used on an ordinary desk and eliminates the need for much specialized hardware.

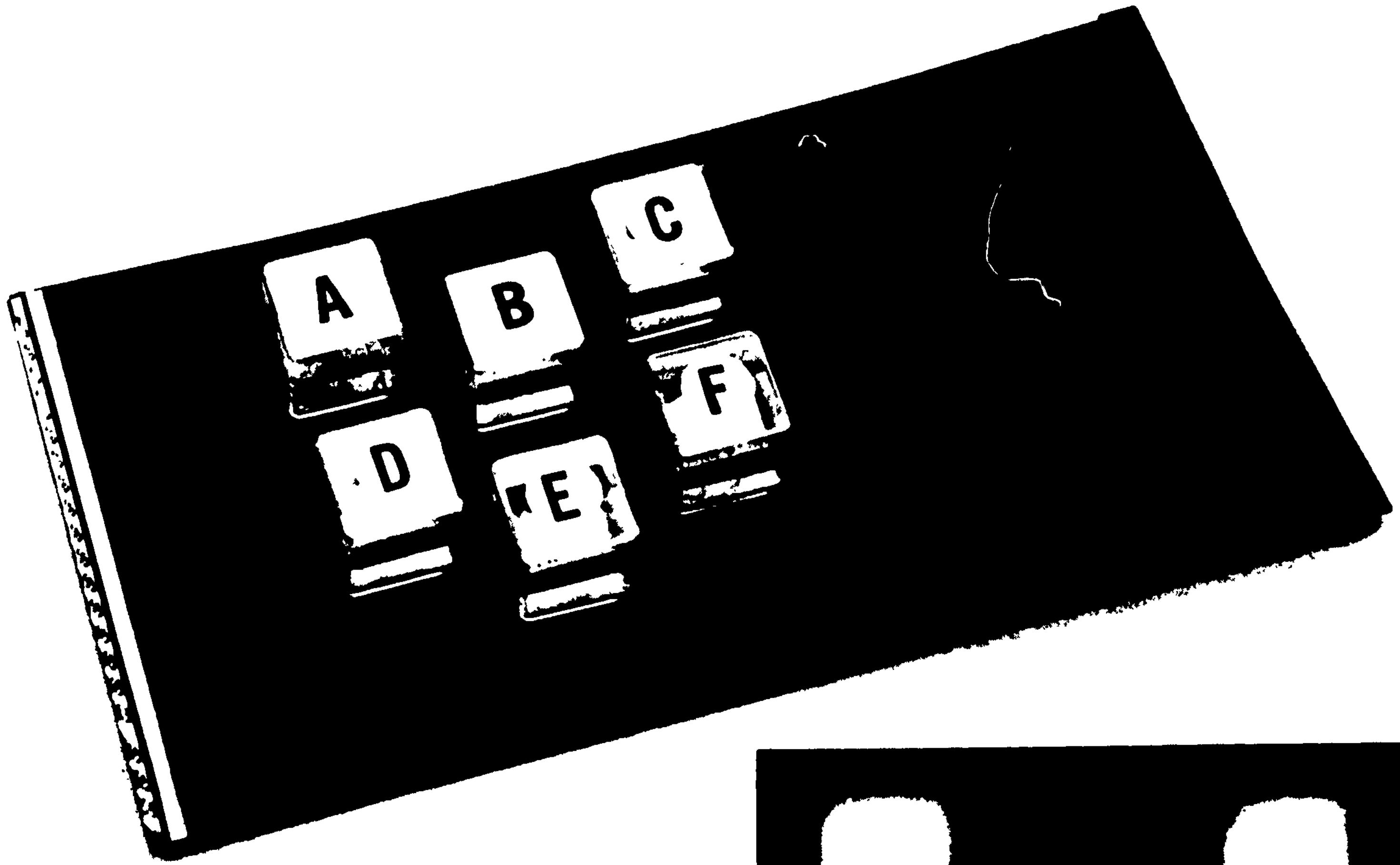
Mixtures, Pure Substances, and Elements

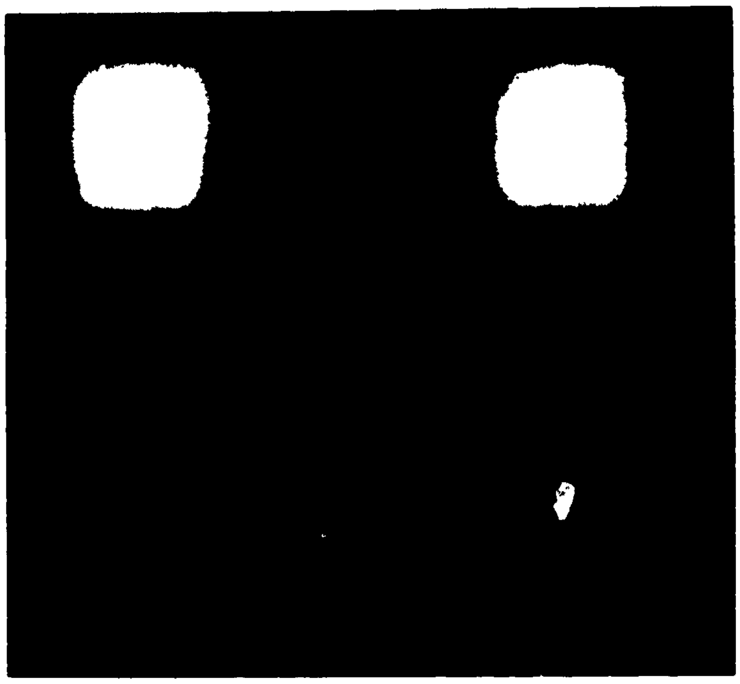
The course proceeds to the separation of mixtures. We use all these characteristic properties to break up what we find in front of us into as many components as we can. We use the available tools quite indiscriminately, and we remind our students that men used these tools long before they knew there were such things as physics and chemistry. For example, people knew about grain alcohol for several thousand years and used it as a solvent, without any chemical theory. We also are going to use it as a solvent, without asking what happens or why. The fact is that if I put one substance into alcohol, it dissolves; some other substance does not. Here I have a way of separating substances.

From the separation of mixtures we get the idea of a pure substance; we define it by certain rules of the game. We start with something; we heat it and freeze it and dissolve it and filter it. We keep doing all kinds of things to it, and we keep getting back the same substance; the material does not separate into two components which react differently. We say that this is a pure substance. With these rules we define pure substances and we see that, unlike the mixtures, they have definite characteristic properties.

Here the rules of the game are applied in practice and in our text: You get something. You try to break it up into components by whatever techniques you have developed. (Other techniques, which are beyond the reach of the student laboratory, are described in the textbook.) Then you measure the characteristic properties of your sample of matter and you check them against a table of data. If there is such a combination of properties tabulated, it has a name, and you say, "Aha, I have so-and-so." And if it does not have a name, you may call it whatever you wish.

Now we add to our arsenal. Instead of just distilling and freezing and crystallizing and so on, we permit a wider range of tools, such as heating with charcoal and boiling in hydrochloric acid to break up those few substances which would not break up under the previous treatment. This is how we get to the idea of elements, by way of an operational definition. Elements are those things that do not break up into simpler components, even when they are put in acids or heated or subjected to electric currents, or treated in certain other ways.





An experiment to demonstrate radioactivity, as a step toward the atomic model of matter. Samples of six different substances in small plastic boxes are placed on a photographic film enclosed in black paper. After three days some parts of the film are found to show effects like that in the photograph at the right.

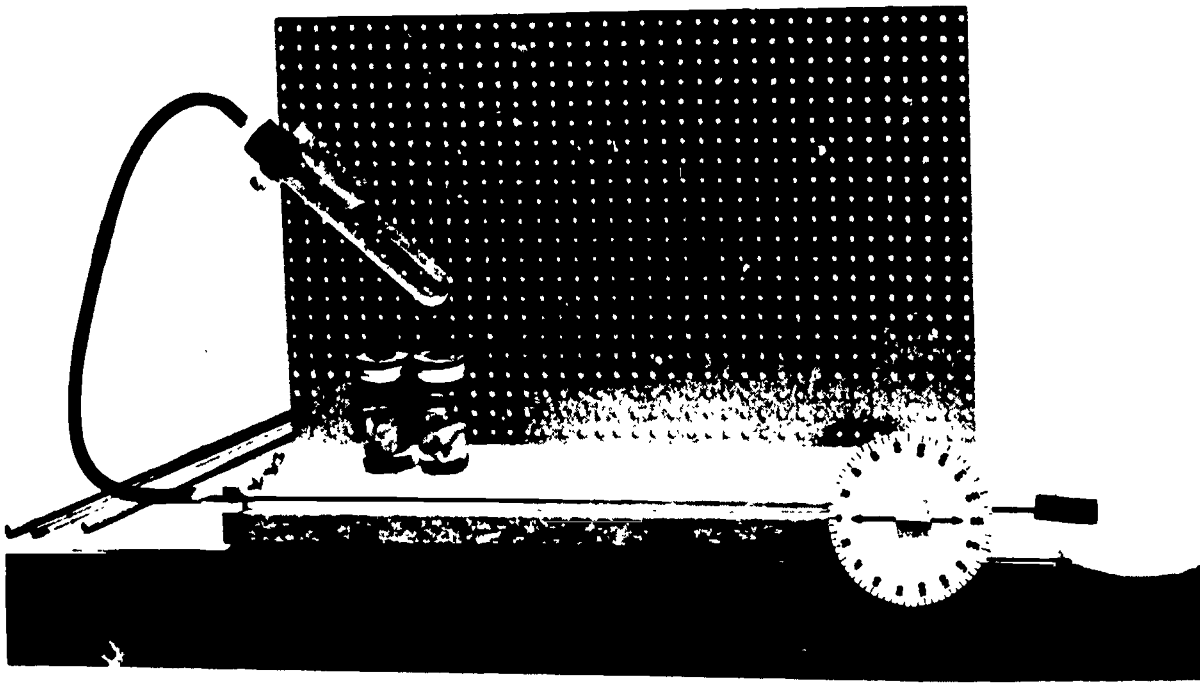
Radioactivity

Ultimately, we want to get an atomic picture of matter. But if we are really honest and do not just rely on our beliefs, we find very little to suggest atoms in anything which we have described here. When you pour water, it looks continuous; if you look at crystals of salt, the crystals are big; they dissolve, and there are no more crystals, and the resulting liquid looks continuous. We need something to give us some hint, some real indication that there is a discreteness in all matter.

We have chosen a path through radioactivity to the atomic picture, because radioactivity is one area where discreteness is very much in the foreground. Anybody who has ever heard a Geiger counter click knows what I mean by discreteness. Discreteness is apparent in the grains of a photographic film exposed to radioactivity. Even though the intensity of the radiation may vary, the grains are always the same size (with the same kind of film). The tracks in a cloud chamber also give a strong impression of discreteness.

Now you may say this is just radioactivity, a special phenomenon; where does matter come in? Matter comes in because, after many clicks, you find that you have collected a quantity of a new element.

Previously, the word "atom" has nowhere appeared, but now we offer the suggestion that all matter may be made up of particles. We say that we can count individual particles, and if we count long enough we can see a measureable amount of gas. Incidentally, we plan to do this experiment by brute force on film, using a large



Apparatus for measuring the thermal expansion of a long tube. Steam from boiling water in the test tube passes through the length of the tube, heating it and causing it to expand. The left-hand end of the tube is held firmly by a clothespin, preventing this end of the long tube from moving. The right-hand end of the tube is free to move, and its expansion is amplified and measured by the rotation of the circular scale.

amount of radioactivity, 20 curies. You will see the spectra of the resulting gas and see that it is helium.

The Atomic Model

Now we come to the second part of the course, where we theorize and make a model. We reexamine what we have done before, but now we begin to do some abstraction. We start slowly, building up as we go — which is the way that science works, in fact. The first idea we propose is that there are particles; these are probably very small, because we never notice them in daily life. The minute we make such a statement to the youngsters, we have accepted an obligation to say how many and how small; otherwise it is a meaningless statement.

We say that the atoms are very small things which are different for each element, and that in chemical combination they are grouped together in molecules. This very simple picture already correlates a great deal of information which we have gathered in this course. It explains how we can get an element back out of a chemical combination; all chemical reactions are, in this language, a regrouping of existing things. It makes sense that the total mass remains constant in reactions if we believe that atoms only change positions or change their combinations. Each pure substance, each compound, always has the same composition because we always take so many of one kind of atom and combine it with so many of another kind.

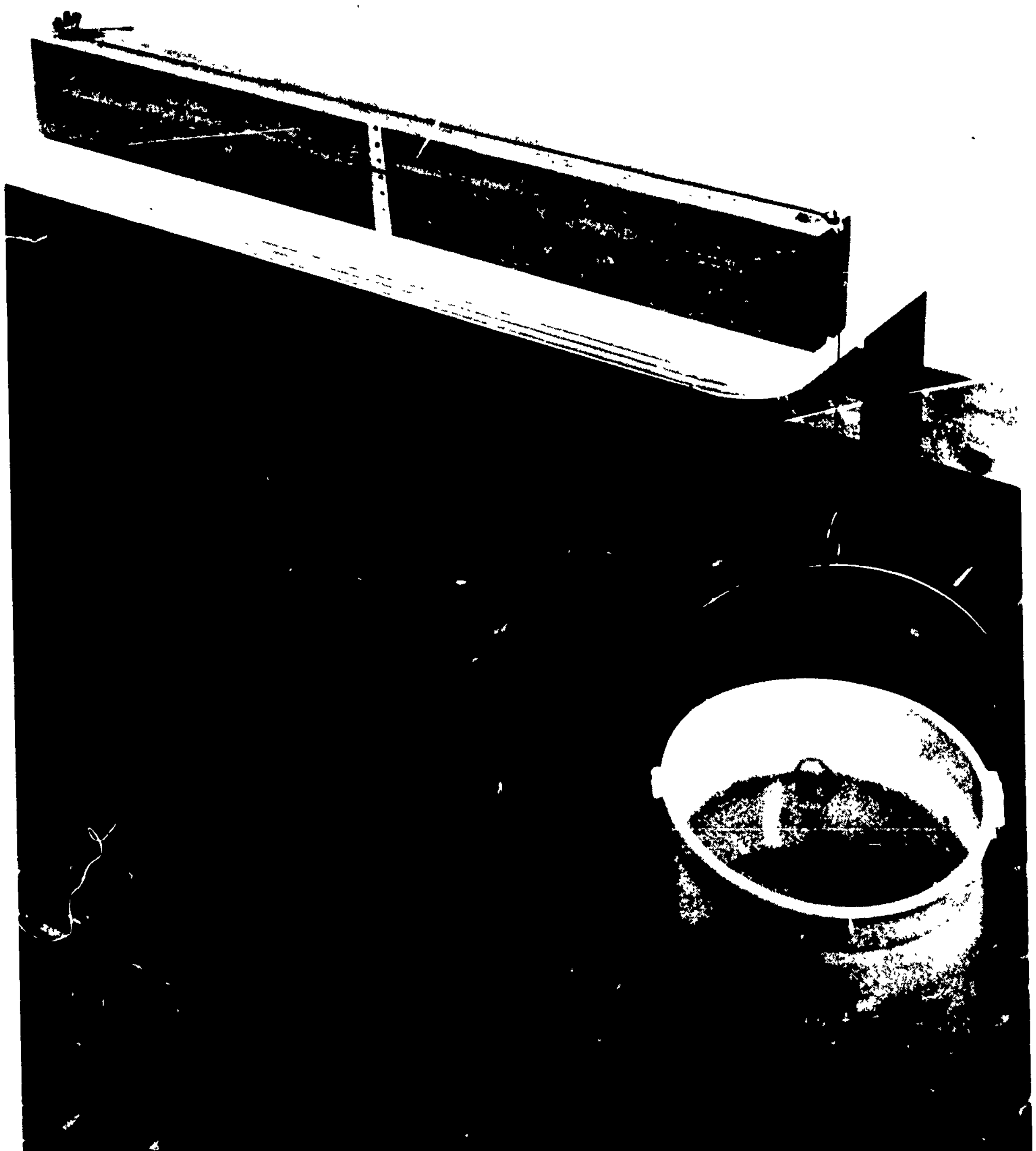
So far we have used only the discreteness, but now we can see also that there are more properties than that. We recall that there are some solids which have high density and are very hard to compress. Apparently these atoms act like hard objects touching each other. Gases are very easy to compress and have a low density. Apparently these atoms are far apart, so the low density and the compressibility also fall in line and make a sensible pattern. With oleic acid we can find the thickness of a monolayer and thus get the size and mass of a molecule. So far, our atoms are static; they have a certain size and are a certain distance apart.

The Kinetic Picture of Heat

Now we come to the next phase, where we let the atoms move. Everybody knows that if you open a bottle of gas, the gas will come out; this leads to the idea of molecular motion, and to the molecular picture of heat. We have been using heat all along, but now we want to relate the thermal properties to the atomic picture just as we did the chemical properties. We start the discussion of heat and the gas model of heat without any detailed laws of mechanics, but we make use of analogy. We theorize a molecular picture of two very basic concepts in physics, the temperature and the quantity of heat (which are confused no end by students). We move from the gas into the solid and get the idea that hot molecules and atoms move faster than cold. We say that if things collide, the fast ones slow down and the slow ones speed up; that if you heat something it becomes warmer, because you make its molecules move faster; and so on. This brings us to the ideas of thermal energy.

In the final chapter, thermal energy is measured in calories by its heating effect on water. Specific heats are determined, and then heats of reaction, solution, fusion, and vaporization are studied. These latent forms of heat, not associated with molecular motion, are related to the rearrangements of atoms in chemical reactions, solution, and changes of state.

In summary, we believe that this course will greatly facilitate the teaching of physics and chemistry: several chapters of chemistry can be eliminated and much of the first part of PSSC will not be needed. But, most important, we believe that pupils will enter physics and chemistry with an improved orientation and attitude toward science, and well-equipped with essential skills.



The stretch of a wire when it is pulled can also be measured by an amplifier. The wire is fastened to a small metal drum that rotates as the wire stretches. Attached to the drum is a long pointer, which amplifies the stretch of the wire.

IPS Leadership Training Program

By GERALD ABEGG
IPS Group, on Leave from Kansas State Teachers College
Emporia, Kansas

Widespread acceptance of the Introductory Physical Science Program has resulted in a severe shortage of qualified teachers to implement the Program. Summer and in-service institutes, sponsored by the National Science Foundation, have contributed significantly to the pool of trained IPS teachers, but the supply falls far short of the demand. In addition, several areas of the country

Gerald Abegg at the Leadership Conference map.

which have not made much effort in IPS teacher training are making large-scale adoptions of IPS. When school administrators in these areas sought to solve their IPS teacher-training problem with local or regional workshops, they found that IPS workshop teachers were extremely scarce or non-existent.

In an effort to increase the quantity and quality of IPS teachers, the IPS group obtained a grant from the National Science Foundation to support a leadership program. This program is designed to locate qualified science teachers and to prepare them to instruct other teachers in the use of IPS.

Late in the spring of 1968, information notices on the leadership program were distributed to school districts which had reported a need for trained IPS teachers. In addition, the publisher of the IPS textbook distributed notices and application forms to teachers in schools making IPS adoption for the 68-69 school year. Potential participants in the program submitted applications in which they indicated their teaching experience, commitments to teach IPS in the ensuing school year, plans for a local IPS workshop for other teachers, and ability to participate in the total program. In each case, the participant's school district was requested to present a letter indicating a willingness to support the individual in the organization of the local workshop.

After 114 applications had been reviewed, eighty-seven teachers were selected to participate in a summer Leadership Conference held at the Colorado School of Mines in Golden. The participants received no stipend for the 2½-week conference, but were provided round-trip transportation from their respective home towns, room and board, and miscellaneous expenses. Seventy-eight teachers accepted the invitation to participate in the conference and arrived in Golden on June 16 to begin the intensive training program.

The Leadership Conference was designed to prepare the participant to teach IPS in his own classroom and to conduct a local workshop for his peers who are also teaching IPS. Since nineteen of the conference participants had some experience in the teaching of IPS, they were assigned to a special work group with the task of studying some of the IPS experiments in depth, as well as providing a source of personal experiences which were shared with the remaining participants. The latter were divided into four small discussion groups to facilitate concentrated study of the full IPS program. The staff at the conference rotated among the five groups in an effort to keep the various working sessions fresh and to permit the maximum interchange of ideas between staff and participants. Film showings, testing, and major presentations were held in a lecture hall, with all other work divided between classrooms and the laboratories.

During the late afternoon and evening hours, small group conferences were scheduled to complete the details of the local workshops which the participants were to conduct. The schedule for these local workshops was set at five full days' instruction prior to the opening of school, and ten full days during this academic year. In a few cases it was necessary to devise a plan involving 15 or 20 partial day sessions, but in all cases the local workshop was designed to meet for a minimum of 100 hours of instruction.

Personnel from the IPS staff are scheduled to visit each of the local workshops during the in-service phase to aid in resolving implementation problems and to evaluate the overall effectiveness of the workshop program. At the conclusion of the local workshop, each participant who is concurrently teaching IPS will be issued a certificate indicating his or her participation and successful completion of the program. In the large majority of school districts, this certificate will be recognized as professional credit earned by the teacher.

A special grant by the publisher will pay one-half of the workshop instructor's salary, with the district or districts sharing the costs of the additional salary and expendable supplies used in the workshop.

The Program at Work

Approximately 50 workshops met for the five-day pre-school session in August and are now involved in the in-service phase. As a result of severe financial problems and local organizational difficulties, it was necessary to delay the remaining workshops until the summer of 1969. These workshops will thus coincide with the full-scale implementation of IPS in the regions they serve.

In October and November, each of the Leadership Conference participants attended one of seven regional three-day meetings. These follow-up sessions provided an opportunity for each of the participants to discuss his or her local workshop with the IPS staff and other participants. Many problems were identified and solved in these discussions.

The feedback from these meetings indicated that the summer training session was quite effective in preparing the participants for their respective workshop assignments. Naturally, some leaders are more successful than others in relating to their peers and in taking full charge of the situation.

In the final analysis, the most critical problem has been created by local school officials who are reluctant to support the workshop effort. Some school officials have attempted to reduce the workshop to a series of informal chats, while others have insisted that the workshop instructor could not be paid from local funds. In addition, more than half of the workshops are conducted on the teachers' time on Saturdays and evenings.

In situations where the district awards salary credit for the successful completion of the workshop, the teachers are pleased with the arrangements; however, teachers are quite unhappy in the few situations in which neither credit nor released time for workshop attendance is provided. The problems created by these undesirable situations have resulted in a very poor attitude in all involved. The workshop leaders indicate that the five-day preschool meeting is the most valuable part of the workshop plan. They agree that this is largely due to the feeling of fellowship developed in the day-long sessions as well as the anticipation of school opening. The in-service phase of the workshops is constantly plagued with interfering and conflicting activities; the workshops that suffer from lack of administrative support seem to be most affected by these scheduling and attendance problems.

Although the number of teachers involved is not as large as anticipated, more than 350 teachers from 21 states are participating in the local workshops. In addition many school districts which for any of several reasons were not able to organize a workshop this year, have already scheduled a 15-day session for next year.

While the problems of communication and coordination seem insurmountable, the interest and cooperation generated among the teachers and administrators at the local level appear to be one of the strengths of the program. In a large number of situations, the IPS local workshop is the first attempt at training teachers through their peers and within their own environment. Several colleges have made arrangements to provide facilities and credit for the local IPS workshops. The willingness and ability of the local schools to adapt the IPS Leadership Training Program to their respective situations is the key to the success of the entire program.

TESTING

Measuring Student Achievement

By JOHN H. DODGE
IPS Group

The purpose of the IPS course is to give all students a beginning knowledge of physical science and to offer some insight into the means by which scientific knowledge is acquired; the method employed to achieve these goals is one of student experimentation and guided reasoning on the results of such experimentation. In measuring achievement in the IPS, one would like as far as possible to evaluate progress of students in terms of these goals.

No method of measuring achievement can be entirely satisfactory. Some sort of selection of items to be tested is necessary, and one can only hope that the selection made is representative of the whole of the students' knowledge and understanding. Nor is it easy to be certain that a student's response to a test item is dictated solely by the instruction he has received; his behavior is the result of the influences of all factors that have been brought to bear on him, not necessarily limited to those encountered in a particular class. And there is no guarantee that any particular test item is in fact a valid measure of the desired attitude or understanding.

It seems well, therefore, that a teacher should estimate student achievement in a variety of ways, rather than limit himself to a single technique applied at wide intervals.

Here are some of the things a teacher can do to appraise a student's progress:

Observe and make a few simple notes on the student's performance in the laboratory.

Make some notation regarding the student's participation in class discussions.

Inspect the solutions to the assigned problems in the Home, Desk, and Lab section at the end of each chapter.

Inspect from time to time the laboratory notebooks for completeness, accuracy, readability, and clarity.

Give short quizzes (five minutes or so) on an advance reading assignment or on material just completed.

Give laboratory tests.

Give the chapter quizzes suggested in the Teacher's Guide.

Give the IPS Achievement Tests.

Generally, the more notations a teacher makes in his record book about each student, the easier it is to explain a report-card mark to parents, counselors, and administrators. Many of these notations can be made without grave interruption to class progress. For example, during student work in the laboratory the teacher can keep his eye on what is going on, and at the same time check notebooks and other written work.

Students learn to adjust rapidly to what a teacher requires. If the teacher never pays more than superficial attention to laboratory reports or other written work, concentrating only on general appearance and neatness, the students will supply him with clean and neat nonsense. On the other hand, it is usually impossible to perform the immense labor of scrutinizing with care every word that comes in. A wise teacher will select from time to time representative laboratory reports or solutions to Home, Desk, and Lab problems and will examine them carefully, assigning them grades representative of the knowledge and understanding of science the papers actually show. Certainly no *grade* should be entered for a student in the teacher's record book unless it represents a defensible estimate of the student's attainment of the goals of the course. It is far better to enter a relatively small number of meaningful grades in the record book than many that do not represent valid estimates of the student's progress.

The time devoted to formal testing should not be excessive. It is recommended that the Achievement Tests be used as appropriate; if the giving of one of these tests is not practical during the period covered by a report card, one or more of the chapter quizzes in the Teacher's Guide might be used instead, the teacher choosing the number and combination of questions from the quizzes that is appropriate to the time available. In a report-card period of thirty school days, two days are probably sufficient for formal testing.

Chapter Quizzes

Bound in the IPS Teacher's Guide is a series of quizzes, one for each chapter except the first. Most of the questions are objective, requiring the student to select one of five possible answers to the question posed. However, other types of questions are included as well: those that require a student to read and interpret a graph, make and exhibit calculations, or write an explanation in a paragraph of a few carefully constructed sentences. As suggested above, the teacher may use the quizzes in whole, in part, or in any desired combination; he is free to reproduce them in quantity for his classes.

These quizzes have been so constructed that the distribution of correct responses will resemble that of the Achievement Tests, although the quizzes have not been given a formal analysis. They were used by pilot teachers, whose comments and suggestions are incorporated in the present edition.

Achievement Tests

Questions for Achievement Tests are prepared in the same spirit that governs the preparation of Home, Desk, and Lab problems. Little use is made of questions designed only to test a student's memory; usually, situations are presented in which there is some element slightly different from those the student has specifically worked with in the laboratory or in the textbook. Hence, some judgment is usually required of the student, based on his understanding of principles and procedures.

The questions selected are of the type that present a situation and offer five possible responses to it, of which the student must pick the single correct one. An attempt is made to provide incorrect responses that correspond to errors students are likely to make when their knowledge and understanding are inadequate, so that student responses may indicate where instruction should be improved; however, we have not succeeded in doing this in all cases.

As an example, consider the question reproduced on the opposite page.

The question is based on an important experiment performed in Chapter 3 on Characteristic Properties, and on the discussion that follows it. In this experiment the student heats a test tube containing either paradichlorobenzene or naphthalene in a water bath until the solid is melted and raised to a temperature of about 90°C; then the substances are allowed to cool, the student recording the temperature of the water and that of the substance in the test tube until the substance has completely resolidified. The student then prepares a graph of his data, and in a class discussion the graphs of all the students are examined and compared.

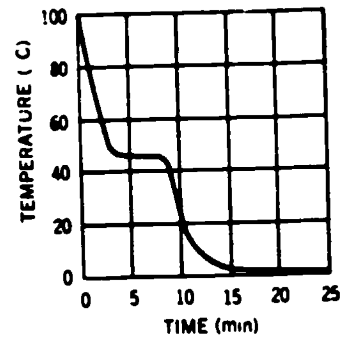
From this experiment, the student learns that the cooling of a liquid that does not freeze in this temperature range exhibits a regular, smooth temperature change. However, when the liquid freezes, the temperature remains stationary during the change, at a point which depends on the particular substance but is independent of its quantity, provided that the substance is not mixed with another.

The question presents a situation similar to that of the experiment the student has performed. The graph presented as a part of the question indicates that the substance is a single substance with a freezing point of about 45°C, as indicated by the horizontal section of the cooling curves. The student is expected to understand that using the larger quantity of the substance would not affect the existence of the horizontal section of the graph nor the temperature at which it occurs; but that if the apparatus and procedure were the same, it would probably take longer to cool and to freeze. Hence the correct response is (C).

Responses (A) and (B) would probably be selected by students who have not learned that the freezing point is characteristic of the substance and not of the quantity of it, but think that doubling the mass would change the freezing point. Since the new quantity of substance is double the original amount, these wrong choices give the student the choice of a centigrade temperature double the original freezing point or one-half of it, depending on which way he thinks the quantity of substance changes its freezing point.

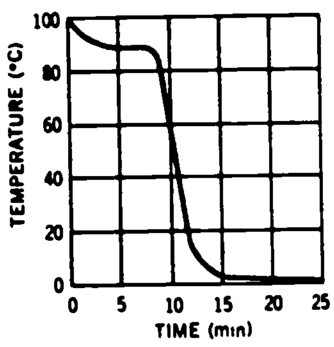
Response (D) gives the careless student a chance to confuse the substance undergoing solidi-

4. 10 grams of a substance is heated until it melts, then it is allowed to cool in a freezer whose temperature is O° C. While it is cooling, the temperature is recorded each half minute and the graph at the right is plotted from the data obtained.

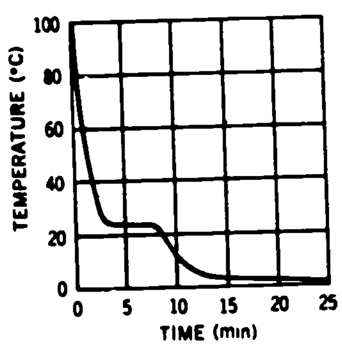


Had 20 grams of the substance been heated and cooled, which graph below would best represent the temperature of the substance as a function of the time?

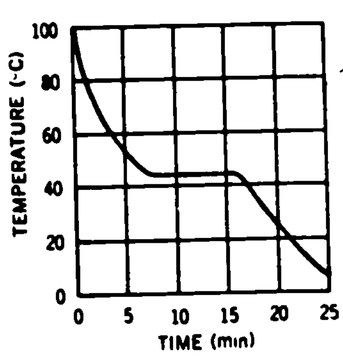
(A)



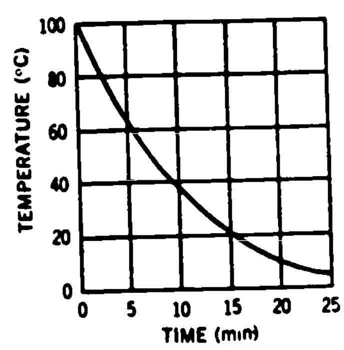
(B)



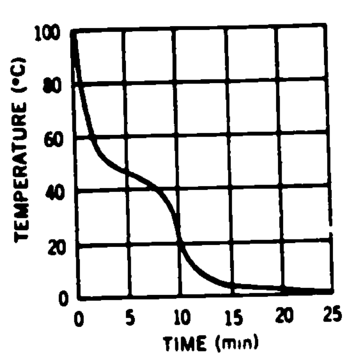
(C)



(D)



(E)



fication with one that does not. The graph offered here resembles the one he prepared in the experiment performed with water.

Response (E) gives the careless student a chance to confuse the solidification of a single substance with that of a mixture of substances. He has not studied the cooling of mixtures in the laboratory, but this is a part of the discussion following the experiment, and a cooling curve of a mixture of substances — candle wax — is printed in the text.

The selection of the correct response shows that the student understands the particular point; if he selects other responses, there is some indication of the nature of his misconception and a hint as to what might be done to straighten him out.

All of the Achievement Tests have been tried out in selected pilot schools, with enough students taking the tests so that meaningful statistical analyses could be made by the Educational Testing Service. On the basis of these analyses, faulty questions were eliminated, revised, or replaced. The published tests are therefore likely to be more satisfactory than the objective tests a particular teacher makes up for his own classes; moreover, the teacher who uses them has the means of comparing the performance of his students with that of the pilot group of students.

In order to relate the statistics obtained from the analysis of the tests to the general ability of the students, two sections of the School and College Ability Test were administered to the students in the pilot groups. It turned out that the students in the pilot group in which the Series A and Series B tests were tried out were definitely above the national average in ability. Therefore, the Series C tests were designed to be somewhat easier than Series A and Series B so that they would be more appropriate to use with less able groups. A special effort was made to form the pilot groups for the trial of the Series C tests from a more representative section of the student population. These groups also took the SCAT test, and an analysis shows that these Series C trial groups contain students that are indeed representative of the average school population in the United States.

Laboratory Tests

Since the laboratory forms an indispensible part of the IPS course, and the success of the course depends on the ability of the student to skillfully perform laboratory investigations and to interpret them properly, it is appropriate to administer tests to measure achievement in the laboratory.

Limitations of time, space, and equipment usually require that the conduct of a laboratory test be on a considerably less formal basis than that of the Achievement Tests or the quizzes. The emphasis should be on the actual technique adopted and the reasoning involved in the investigation, rather than on the student's memory. All chemicals and equipment used in the IPS course are made available, and the student is permitted access to his textbook and laboratory notebook. Like the laboratory work itself, the laboratory tests are usually performed by pairs of students, so that general discussions are necessary. The teacher observes the activity carefully, making notes to assist his evaluation. When the test is complete, he bases his final evaluation on the reasoning of the students and the evidence they offer for their conclusions.

One of the laboratory tests — the Sludge Test — is lengthy, requiring about four or five laboratory periods; the students separate the components of a complex mixture and describe them as accurately and completely as possible. Details are given in the Teacher's Guide; this test is appropriate immediately following Chapter 5.

Three other laboratory tests are bound separately, and are appropriate for use at later points in the course. None consumes as much time as the Sludge Test, two of them requiring about two laboratory periods each, and each of the two parts of the third requiring about one laboratory period.

Suggestions about the grading of laboratory tests are given in the booklet.

IPS Achievement Tests

By RAYMOND E. THOMPSON
Educational Testing Service
Princeton, New Jersey

Achievement tests have been an integral part of IPS since the inception of the course. Prepared and revised by the same people who developed the course, they provide a measure of student attainment of its objectives at several levels. The performance of an individual on a particular question (one concept), the attainment of a class on a given test (a course segment), and the achievement of a broad sample of students on an entire series of tests (the course) are all measured.

There are now three series of IPS Achievement Tests designated A, B, and C. The tests in series

A and B are intended for the typical student in IPS and are at the same level of difficulty.

The tests in series C are easier than those in series A and B. In series A and B there are four unit tests; each test is based on about three chapters of the IPS course and contains approximately 30 objective questions. There are currently four tests in series C, but a fifth test will be added. Each series C test deals with about two chapters and contains approximately 25 objective questions. Any of the tests can be administered in one class period of around 45 minutes.

The performance of samples of IPS students on each of the test questions has been extensively analyzed. These analyses showed for each question the proportion choosing each option and the correlation between success on the question and success on the complete test in which the question appeared. Furthermore, the number of students from each fifth (high to low) of the distribution in terms of score on the complete test who chose each option was found. Finally, a measure of the complete test performance of those students choosing each option of the question was computed. These statistics guided the selection and revision of questions and made it possible to construct final forms of the tests with the desired difficulties and discriminating powers.

Measures of the performances of IPS students on earlier versions of tests in all three series are now available. The data are presented in Table 1. The data for the tests in series A and B are based on IPS students believed to be typical. The data for the tests in series C are based on a sample of lower-ability IPS students.

The available tests are not identical to the ones listed in this table, but have some questions eliminated and others changed.

The statistics in Table 1 are based on rights-only scores. The reliability of a test is an index of the consistency with which the test ranks and measures students' performance. Reliability is a function of a number of factors. It is maximized when the number of test questions is large, the diversity of the student group is great, the average difficulty of the questions is 50 per cent, and the discriminating power of the questions is high.

For the same students on whom the data in

Table I

Measures of Performance on IPS Achievement Tests

Series		Test 1	Test 2	Test 3	Test 4
A	Number of Students	1,818	1,632	1,170	370
	School Year	'64-'65	'64-'65	'65-'66	'65-'66
	Chapters Covered	1-3	4-6	7-9	10-11
	Number of Questions	26	30	30	30
	Mean Score	13.5	17.1	16.6	15.4
	Standard Deviation	4.9	5.6	6.4	6.1
	Reliability	.80	.81	.87	.83
B	Number of Students	2,785	2,405	1,990	195
	School Year	'66-'67	'66-'67	'66-'67	'67-'68
	Chapters Covered	1-3	4-5	6-8	9-11
	Number of Questions	31	33	32	33
	Mean Score	13.6	18.2	18.2	17-9
	Standard Deviation	5.9	6.4	5.6	5.4
	Reliability	.82	.85	.83	.78
C	Number of Students	425	400	165	320
	School Year	'67-'68	'67-'68	'67-'68	'67-'68
	Chapters Covered	1-3	4-5	6-7	8-9
	Number of Questions	25	25	25	22
	Mean Score	13.3	13.5	14.9	9.2
	Standard Deviation	4.6	4.5	5.2	4.7
	Reliability	.77	.74	.83	.81

Table 1 are based, the percentile scores in Table 2 have been computed. Again, it should be noted that the data for the series C tests are based on lower-ability IPS students.

Table 2

Estimated Percentile Scores for IPS Achievement Tests

		Test			
Series	Percentiles	1	2	3	4
A	90	21	26	27	25
	75	18	22	23	21
	50	14	18	18	16
	25	10	15	12	12
	10	7	11	9	9
B	90	23	28	27	26
	75	19	24	24	23
	50	14	19	19	19
	25	10	14	15	15
	10	7	11	12	12
C	90	21	21	22	17
	75	18	18	20	14
	50	14	14	16	9
	25	11	11	12	6
	10	8	9	9	5

The students on whom the data for tests in series A and B in Tables 1 and 2 are based came from a variety of schools and were taught by many different teachers. Most were ninth-graders, but many were eighth-graders; they represent a considerable range of academic ability. They are believed to be typical of the students who were taking IPS in the indicated school years.

The dependence of test performance on grade level and scholastic ability was studied in detail for a large group of students believed to be representative of IPS students in the 1965-66 school year. In that year 1,005 ninth-grade IPS students and 400 eighth-grade IPS students took the School and College Abilities Test (SCAT), Survey Form, a test of verbal and mathematical ability. The results shown in Table 3 make it clear that these IPS students were more scholastically able on the average than typical junior high school students in the nation.

Table 3 shows, for example, that a ninth-grade IPS student who earned a SCAT converted score of 297 was placed at only the 50th percentile in this IPS group, but at the 90th percentile in the national sample. Put another way, an IPS student who was superior to only half of this IPS group in scholastic ability was superior to 90 per cent of the national sample. These IPS students were sorted into six sub-groups on the basis of grade

Table 3

Scholastic Ability of IPS Students in the 1965-66 School Year

Grade Level	SCAT Converted Score	Approximate Percentile in This IPS Group	Approximate Percentile in National Sample
9th	308	90	97
	302	75	93
	297	50	90
	290	25	70
	282	10	50
8th	306	90	98
	301	75	97
	295	50	93
	285	25	75
	276	10	40

Table 4

Performances on IPS Tests (Series A) by Grade Level and Scholastic Ability

		Test 1		Test 2		Test 3		Test 4	
Grade	Scholastic Ability	No. of Students	Mean Score	No. of Students	Mean Score	No. of Students	Mean Score	No. of Students	Mean Score
9	High	189	18.9	206	23.8	137	23.6	73	20.0
	Middle	398	15.3	433	19.7	291	18.3	113	15.1
	Low	288	11.3	310	14.3	227	12.0	42	11.2
8	High	82	16.8	57	21.5	34	20.0	38	19.0
	Middle	110	13.4	81	16.2	43	15.0	26	16.3
	Low	104	9.7	56	13.1	51	8.6	4	19.0

level and scholastic ability. The performances of these six sub-groups on the IPS Tests in series A are indicated in Table 4.

The same criteria were used in sorting the students into six sub-groups for each test. For the ninth-graders a percentile score on SCAT of 80 or higher in the IPS group (95 or higher in the national sample) placed a student in the high sub-group; a percentile score of 30 or lower in the IPS group (80 or lower in the national sample) placed a student in the low sub-group. For the eighth-graders a percentile score on SCAT of 70 or higher in the IPS group (95 or higher in the national sample) placed a student in the high sub-group; a percentile score of 30 or lower in the IPS group (80 or lower in the national sample) placed a student in the low sub-group.

Table 4 indicates that the higher the grade level and the higher the scholastic ability of a student, the higher his performance on the IPS Tests can be expected to be. There are only two exceptions to this general trend. These exceptions are the mean scores of eighth-grade students in the middle and low sub-groups on IPS Test 4. However, these means are based on only 26 and 4 students, respectively, and they should probably be discounted.

The series C IPS Tests are designed for lower-ability students. A deliberate attempt was made to include easier and fewer questions in the series C tests. The measures of test performance in Table 1 for the series C tests are based on a group of lower-ability IPS students. In the 1967-68 school year SCAT (Survey Form) was given to this group of 511 lower-ability IPS students; nearly all of these students were ninth-graders. The scholastic ability of this group is indicated in Table 5.

Table 5

Scholastic Ability of IPS Lower-Ability Ninth-Graders in 1967-68 School Year

SCAT Converted Score	Approximate Percentile in This IPS Group	Approximate Percentile in National Sample
295	90	93
289	75	85
283	50	70
275	25	59
267	10	25

Even this lower-ability IPS group was more able than the national sample. But this group is definitely less able than the typical IPS students of 1965-66 whose scholastic ability is described in Table 3.

I shall digress to describe an interesting little experiment that was done in 1968 on the effect of question placement within a test on student performance. Of special interest was the question of whether students were rushed toward the end of the test. Two forms of IPS Test 3 (Series C) were prepared. In Form X the 25 questions appeared in one order; in Form Y the same 25 questions appeared in essentially reverse order. That is, the first question in Form X was the last question in Form Y. Every other student in each class took Form X; the remaining students took Form Y. The test performances of these two presumably equivalent groups of students on the two forms of the test are shown in Table 6.

Table 6

Performance of Equivalent Groups on Two Forms of IPS Test 3 (Series C)

	Form X	Form Y
Number of Students	165	155
Mean Score	14.93	15.03
Standard Deviation	5.16	4.63
Reliability	.83	.78

The mean scores of the two groups on the two forms are not significantly different. In fact, one would expect this difference due to chance alone more than 80 times out 100. Furthermore, no substantial differences in performance on individual questions were found. For 17 of the questions the percentage answering correctly in one group differed by 4 or less from the percentage answering correctly in the other group; for seven questions the difference was between 5 and 10; and for one question the difference was 12 percentage points. No indication of rushing was noted.

In summary, the test performances shown in Table 1 on the series A and B tests are those of typical IPS students, students considerably more able on the whole than the average junior high school students in the nation. The performances in Table 1 on the series C tests are those of lower-ability IPS students, students who are fairly typical academically of junior high school students in the nation.



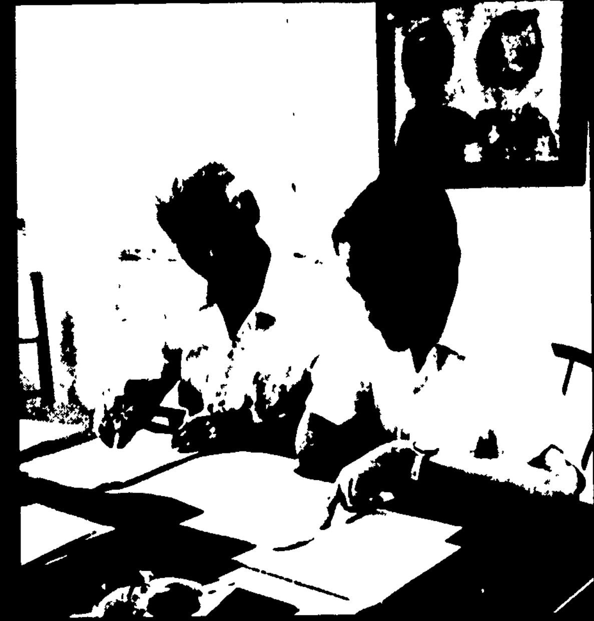


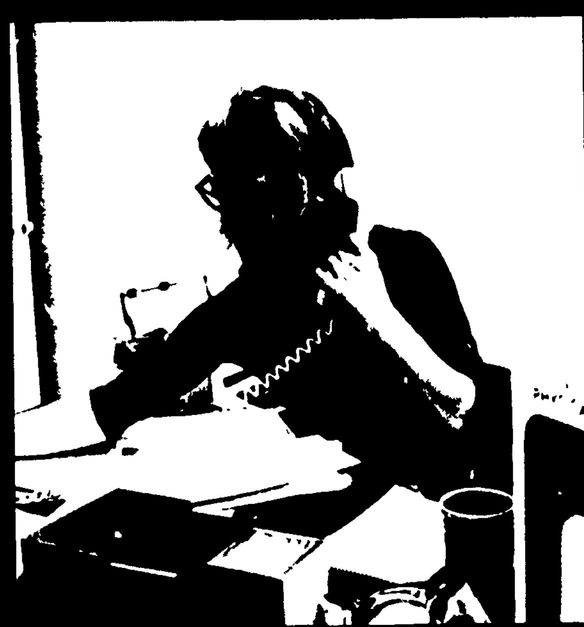







The IPS group





Approved IPS Apparatus

By JAMES A. WALTER
IPS Group

Apparatus for use in Introductory Physical Science is developed in the laboratories of the Physical Science Group of Education Development Center and produced by independent manufacturers. The unusual emphasis in the IPS program on laboratory experimentation as central to the learning process has necessitated stringent standards of performance in this apparatus. The amount the student learns is related to the accuracy of the results of his experiment, and therefore to the reliability of his instruments. Also, frequent use of laboratory equipment demands that it be safe. For these reasons, EDC has instituted a series of thorough inspections as the basis for EDC approval of IPS apparatus. The inspection system consists of an initial inspection of the manufacturer's product, followed by periodic inspections thereafter.

Over the past few years, the periodic and occasional special inspections have been instrumental in correcting faults and keeping the quality of equipment at a high level. For example, the granular copper for one experiment must have the proper grain size for a good reaction. Grains that are too large give no results, and those that are too fine give too rapid a reaction — which is why teachers must not use the electrolytic copper dust for this experiment. One of the periodic inspection trips revealed that a supplier had switched from granular copper to small copper pellets for this item, a change which would have made the experiment difficult or impossible to perform. In another case, it was discovered that the household ammonia solution supplied for an experiment contained soap, which made it unsatisfactory for IPS use.

The equal-arm balance has been given special attention, since it is in many ways the backbone of the laboratory. A set of tests and specifications was made up so that balances could be checked in a uniform way. Fifteen wooden-arm balances from the original production run were used to establish a minimum performance level for an IPS balance in several different tests. New balances are expected to exceed these minimums. On several occasions it was found that balances being produced were below the minimum specifications. In one case it was discovered that the agate bearings in use had too sharp a "V"; in another, the agates had a notch at the bottom of the "V," the result of a regrinding operation that did not go deep enough.

Another case for quick action was revealed by feedback from two teachers who had just received a shipment of new balances. Since the teachers were close by, a team from EDC inspected the balances at the two schools and found that the triangular stock from which the fulcrums were cut had very dull edges that impaired performance. A check of balances at the factory showed the same condition. Production was halted while new triangular stock was obtained; replacements were made in the kits at the warehouse, and new parts were sent out to schools which had received the faulty material.

EDC approval of IPS apparatus is contingent on production of the complete line of IPS equipment and the cooperation of the manufacturer with EDC in its inspection and evaluation program. Any interested producer is welcome to participate.

The basic standard for approval of apparatus or chemicals is the question, "Can the experiments as described in the IPS texts be performed with these materials?" This gives the manufacturer the opportunity to take the apparatus and specifications as developed by EDC and initiate changes in the end product. When prototypes have been developed and tested, the company submits the apparatus and test results to EDC, where the item is again tested and evaluated. When the prototype has been approved, production begins and final approval of the product is given only after an inspection of production items at the shipping point in the warehouse. Following this, the item is spot-checked during periodic inspection, unless feedback suggests something has gone wrong and a special check is required. If a design change is to be made, this whole process is repeated in order that the new design may go on the approved list. After inspection of the initial product, spot checks usually occur at one-year intervals, unless innovations have been introduced in the apparatus, in which case it is subjected to the complete inspection process.

At intervals, the IPS group compiles and issues a status report on the equipment being produced by the approved manufacturers. This list is made available to all interested parties. Comments are made on new items approved, items not approved (if any), and suggestions to check on price where deemed appropriate.

The overall results of this approval system have been to establish a good working relationship between EDC and the producers of IPS equipment, and to maintain the high quality of the equipment supplied for the course.

THE PAPERBACK EDITION

Durables or Consumables?

By EDWARD A. JOHNSON
Assistant Principal, Marblehead Junior High School
Marblehead, Massachusetts

Superintendents, principals, curriculum coordinators, and school purchasing agents are again confronted with one of those seemingly minor problems which call for a simple decision. Yet, as with many "simple" decisions in education, this one can have far-reaching effects.

As recently as five years ago, it would have been considered unusual for many of the better secondary schools in the country to have paperbacks as basic texts. Today, most schools use paperbacks widely for both basic and supplementary texts; librarians are now selecting a considerable percentage of their orders from the soft-cover offerings. The importance of the consumable text is increasing in secondary schools and colleges all over the country.

At Marblehead Junior High School we believe that for our purposes the value of a book is in its content. If we can put more quality materials into the students' hands without substantially increasing the long-term costs, we feel we owe it to the students, the teachers, and the taxpayers to do so.

The IPS course we offer at our school is a good case in point. We prefer the paperbound to the clothbound text because we feel that it offers greater flexibility for both student and instructor. The text actually belongs to the student, so he is encouraged to annotate, to underscore, to compute in the text as the instructor introduces new work or discusses the results of labs just completed. We find that there is a tendency to take greater care of the text when it is one's own. Students are urged to keep the text for reference in later inductive courses which follow IPS.

We feel that the educational advantages of offering the paperback text in this course far outweigh the relatively small amount saved by purchasing the clothbound edition for a longer term.

A Handy Workbook

By ROBERT T. FITZGIBBON
Curriculum Coordinator
Greece Central School District No. 1
Rochester, New York

Over the five-year period during which IPS has been used in Greece Central School District No. 1, all of us who are directly involved with the program have been asked many questions by interested educators in other school districts. One of the most common questions relates to our decision to use the soft-cover text.

Obviously, this decision has resulted in a greater financial obligation for the district. Why, then, use the soft-cover when the program would still be the same with the more permanent text? We, too, asked ourselves this basic question and decided that the program would *not* be the same with the hard-cover text. The rationale is as follows:

1. The paperback text is kept by the student and becomes a handy record book.
2. The laboratory situation of IPS involves a great deal of handling of the text. The paperback format allows students to take full advantage of this situation.
3. We have seen the books used as reference material in later science courses.
4. With the paperback book, pre-lab hints can be jotted down for easy reference. Notes on homework problems can be recorded right in the book.
5. With hard-cover texts, we have to worry about youngsters entering data on graphs, answers to questions, etc., that will interfere with later use.
6. Paperbacks eliminate problems of inventory, storage, and collecting money for lost or damaged books.

Fits the Philosophy of IPS

By ARTHUR G. SUHR
Science Chairman, Hamilton High School
Sussex, Wisconsin

In this school system the school district furnishes all hard-bound textbooks, but students must purchase all paper-bound books. This fact prompted the science teachers to select the paperback edition of the IPS text, since a part of the philosophy of the science program in the Hamilton schools is to encourage the student to design his own laboratory procedures and data tables.

In keeping with this philosophy, the science teachers felt that no attempt should be made to discourage students from using the textbook in any manner they feel is helpful. Students are encouraged to write notes in the text, underline important sections, and write in answers to end-of-chapter problems. They are told to use the book at the lab desks during the lab sessions directly with their laboratory notebooks.

The teachers try not to judge a student response with a single right or wrong but rather use the response to guide students to answers consistent with their observations and calculations. Students are led to defend their answers before the class during the lab and HDL discussions. Using their texts as workbooks helps them to do this.

Being encouraged to jot down notes, questions and answers in the text is a new experience for most students. In many it tends to create a new attitude toward their own importance to the class and also tends to bring about student-centered questions and activities.

The paperback text therefore fits into the philosophy of the IPS approach to science and is truly one of the delights of the program.

The Hamilton School System has used the IPS materials since their general release in 1965. The materials are used in both eighth and ninth grades with approximately 375 students. The school bookstore sells the paperback edition at a minimum mark-up. The total cost of the paperback is less than that of the paperback laboratory guides used in other science classes, and paperback books used in other non-science classes.

Why I Like the Paperback Edition

By JOHN N. MEADE
Newman Junior High School
Needham, Massachusetts

"You mean it's mine?" "I can really keep it?" "Can I write in it?" "Do I have to cover it?"

Questions like these typify the reactions when the paperback edition of IPS is passed out to students every fall. School texts are not the most cherished possessions of kids, but for some reason this book receives care all year. I feel that this attitude is a result of the integral part the book plays in the course.

From an administrative point of view, using the paperback edition reduces the time-consuming task of numbering texts, checking, and then collecting them in June. The relatively low cost allows me to provide each student with a new text every year.

PHYSICAL SCIENCE II

The What and Why of PS II

By URI HABER-SCHAIM

Work on the IPS program started in the early months of 1963 with the object of producing a one-year course in physical science aimed primarily at the junior high school level. This goal remained in force during the years that followed. However, as the use of IPS began to spread, questions like "Where do we go from here?" and "How about more science in the same spirit?" were being asked by teachers with increasing frequency. This gave the impetus for discussions on the creation of a course to follow IPS. What should be its purpose? For whom should it be designed, and what should its content be?

The first few trial years of the IPS program showed that it was serving the two groups for which it was designed: students who plan to take further courses in biology, chemistry, and/or physics in senior high school, and those for whom the IPS is followed only by biology.

In thinking about a follow-up course to IPS it was decided right from the beginning that the new course should also be aimed at a broad spectrum of students, including those who would normally terminate their science studies with biology. Two major topics were chosen for the course. They can be summed up as (1) some of the fundamentals of the chemistry and physics of electric charge, and (2) forms of energy and the conservation of energy. Let us look at each of these topics in some detail.

In the IPS course the students investigate many properties of matter which pave the way for an introduction to the atomic model. However, this introduction is very limited: atoms come in different kinds, they are small, and they are constantly moving. Electrical phenomena were hardly studied in IPS; therefore, there was no need to introduce electric charge into the atomic model. For the student to appreciate the justification and power of the extension of the atomic model to include charge he must first investigate the relevant phenomena.

Here we face a problem: electrical gadgets are familiar to all, but electric charge itself is not directly accessible to our senses as are mass, volume, or temperature. The indirectness of electrical phenomena is probably responsible for some deep-rooted misconceptions: almost all students starting PS II are convinced that when a car battery is "dead" it is "discharged" and all the electric charge in it has been consumed.

In electrical measurements the instruments are more than extensions of the senses; they are the tools which provide the operational definitions of the quantities with which we work. Since the charge that flows rather than the rate of flow is of primary concern to us, the first device used to measure the flow of charge is an electrolytic cell in which hydrogen is collected. With such cells placed at different points in a circuit, it is seen that electric charge is not consumed, that it is indeed conserved throughout the circuit. Once a firm feeling for the flow of charge has been established, the hydrogen cells are replaced by an ammeter and a clock.

So far, all considerations have been in the macroscopic domain. Now we turn our attention to electrolytic processes on the atomic scale and compare the quantity of charge needed to release (or plate out) atoms of various elements. The electrolytic experiments lead to the idea of the elementary charge. They are then coupled to the passage of charge through a vacuum and serve to expand the atomic model to include ions and electrons.

The development of these ideas also illustrates our belief that the restudy of important material in a new context or from a new point of view is an effective way to increase comprehension and retention. In the IPS course we first introduced the law of constant proportions as a generalization of experience in the synthesis of compounds. Later in the course, after the students have learned about atomic masses, we combine the knowledge of these masses and the empirically determined mass ratio for forming a compound to arrive at molecular formulas. In PS II the law of constant proportions is revisited, and the relation between the charge per ion, atomic masses, and combining mass ratio is established.

The next topic which serves as a bridge to the study of energy is the heating effect of a flow of charge. The logic of the experiments done by the students can be summarized as follows: the quantity of heat produced in a resistor connected to a given number of flashlight cells is proportional to the charge that flows through it. When the number of cells is varied, the heat per unit charge is proportional to the number of cells. The number of cells is proportional to the voltage (i.e., what is read on a voltmeter). Therefore, the heat per unit charge is proportional to the voltage, and the total heat equals a constant times the product of charge times voltage (referred to as electrical work). This is the case when the charge flows through a heater, but is it always the case?

Before showing how we use the study of this question as the means of getting at the idea of energy, it may be worthwhile to pause briefly and explain why we searched for a new way to lead to such a seasoned concept. Although the details and the mathematical rigor vary, the main route to energy in courses in Newtonian mechanics starts from kinematics, continues with forces and the laws of motion to get to the subjects of work, kinetic energy, and potential energy, and ends with thermal energy and the conservation of energy. This is an arduous route for many students at any grade level. There are several reasons for this: kinematics is rather abstract and conceptually difficult, in particular when vector kinematics is included. The road is long and largely deductive, with few opportunities for leading experiments. Finally, as in much of physics and most of chemistry and biology it is only the very end of the road which is of interest; that is, energy transfers and energy balance in a system are at the center of interest, whereas the details of the forces and the temporal development of the system are ignored or just not known.

For PS II we wanted an approach which starts with energy changes that are accessible to measurement and can, therefore, be operationally defined without going first through the traditional development of Newtonian mechanics.

As was mentioned earlier, our starting point is the question whether the electrical work always equals the heat produced. By using an insulated electric motor as a calorimeter the students compare heat produced in the motor and electrical work under three conditions of the motor: stalled, freely running, and weight-lifting. It is readily established by experiment that in the last case less heat is produced for the same amount of electrical work. However, the "missing" heat is recovered by letting the weight fall slowly to its original position, turning the motor shaft and generating heat in the motor as it falls.

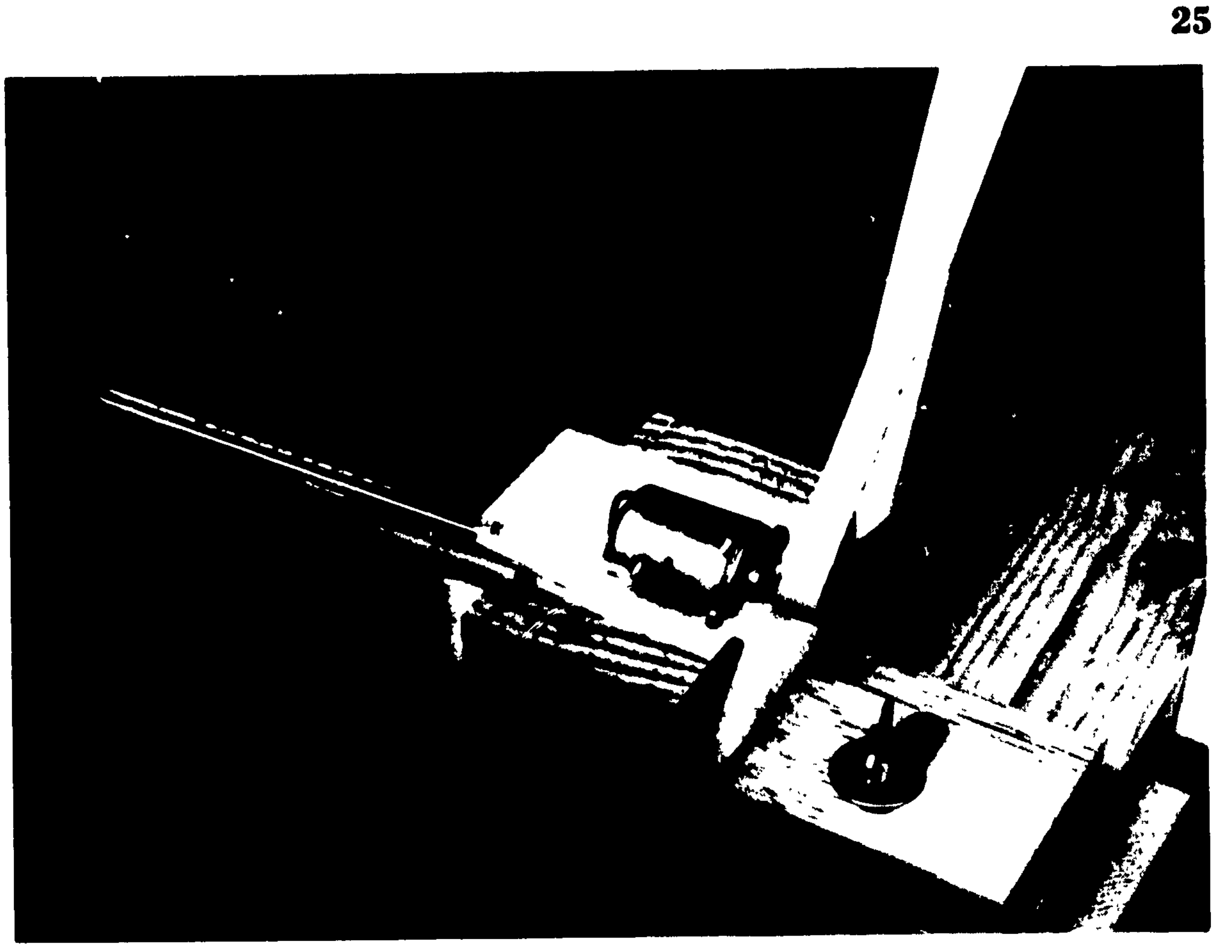
The demonstration that less heat is produced by the same amount of work when there are changes in the configuration of the system is repeated in several forms: less heat is produced in electrolyzing water than in plating copper in a cell containing two copper electrodes. However, when hydrogen and oxygen combine, the "missing" heat is recovered.

Similarly, when a slowly falling weight is accelerating a wheel, no heat is generated. But when the wheel is stopped the quantity of heat which is produced equals that produced when the falling weight generates heat directly by friction.

The complete cycle of missing heat and recovered heat shown in these experiments provides the reason for saying that changes in such diverse conditions as temperature, height, chemical composition, or speed of a body are changes of the same kind; namely, changes in energy which comes in different forms.

This is as far as the course was developed and tried in the pilot schools during the first pilot year (1967-68). A revised Preliminary Edition is currently being tried out on a larger scale.

We plan to continue the course with material on the conservation of energy in general and point out that while the law of conservation of energy can tell us what cannot happen, it is unable to predict what will happen. We hope to conclude the course with a discussion (including experiments) which will lead to a qualitative understanding of the second law of thermodynamics from a statistical point of view. We believe that this rather untraditional topic should be included in this



The heart of the motor experiments. The top half of the insulating box has been cut away to show the position of the motor and thermometer.

course because the conversion of mechanical or electrical energy to thermal energy is part and parcel of everyday processes around us.

PS II in the Science Curriculum

It need hardly be mentioned that a two-year sequence of physical science (either grades 8-9 or grades 9-10) is not now part of the standard science curriculum in American schools. However, we believe that the general features of the most common sequences in the present science program originated at a time when content and methodology of the courses were very different from what they are today. The sequence General Science and/or Physical Science, Earth Science, Biology, Chemistry, Physics had its origin at the time when physical science touched lightly on everything. Earth science was basically physical geography, biology was descriptive botany and zoology, chemistry was the zoology of the elements and their inorganic compounds. Physics was moved to the 12th grade because it required more math than other subjects.

The chemistry required no prior knowledge of physics, and the biology required no prior knowledge of either chemistry or physics. In the context of those courses the sequence made sense.

During the last decade we have been witnessing great changes in the philosophy of science education and in the content and methodology of the courses in the school. Modern chemistry requires a great deal of prior knowledge of physics, including twentieth-century physics. Earth science and biology courses require quite sophisticated understanding of physical and chemical principles and the ability to apply them to complex systems. So there are good reasons for reversing the order of the three science courses in senior high school. But this by itself will not solve the problem, because of differences in enrollment in the three courses: almost all high school students take biology, about half take chemistry, and only about one-fifth take physics. Therefore, the majority of students do not get a sound basis in physical science either for their general education or for use in earth science or biology. One year of physical science in junior high school helps, but it is not enough. A second year of physical science is necessary.

To sum up, we envisage the IPS-PS II combination as a possible foundation for several sequences, ranging from the minimum IPS, PS II, biology to a program for science-oriented students consisting of IPS, PS II, physics and/or chemistry, biology and another year of biology or earth science.

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Physical Science II

Chapter

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Introduction . . . A Measure for the Quantity of Charge . . . Experiment: Do Hydrogen Cells and Light Bulbs Consume Charge? . . . Experiment: Flow of Charge at Different Points in a Circuit . . . The Conservation of Electric Charge . . . The Effect of the Charge Meter on the Circuit . . . Charge, Current, and Time . . . Experiment: Measuring Charge with an Ammeter and a Clock

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14. CELLS AND CHARGE CARRIERS

Experiment: The Daniell Cell . . . Experiment: Zinc and Copper in Different Solutions . . . Flashlight Cells . . . Unintentional Cells and Corrosion . . . The Motion of Electric Charge Through a Vacuum . . . Electrons . . . Atoms and Ions . . . The Direction of Electric Current

*Since this course is intended for students who have had Introductory Physical Science in the preceding year, the chapters have been numbered consecutively beginning with a partially revised Chapter 11 of the IPS text.

15. HEAT AND ELECTRIC CHARGE

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20-21 (IN PREPARATION)

College Admissions and PS II

By ELISABETH LINCOLN
Dana Hall School
Wellesley, Massachusetts

Where does PS II fit into the secondary school curriculum? One aspect of this question is whether the colleges will accept the combination of IPS and PS II as fulfilling their science requirement for admission. To answer this question the college counselor at Dana Hall sent the following letter to about 100 colleges in April 1968.

Letter to the Director of Admissions

Most Dana Hall students take Introductory Physical Science (IPS) in the 9th or 10th grades. In the current year our science club has piloted Physical Science II (PS II), which is an extension of IPS. We would like to include it as part of our curriculum, but need to know how such a course would be viewed for college admission. It is a course developed at the Education Development Center (essentially the same group that developed PSSC and IPS). In some cases no further science would be studied.* Would you accept the combination of IPS and PS II as fulfilling your science requirement of admission?

This letter was accompanied by a description of the PS II course prepared by Education Development Center, and the following comments by our science department:

"The content of IPS and PS II together matches neither a year of chemistry nor a year of physics. The concepts covered are very basic, with each concept derived from evidence in student experiments. The line of approach is to gather evidence, analyze the student data, formulate a conclusion, and use this information to develop a possible model. Predictions can then be made and tested, after which the model can then be modified and added to.

"The conceptual degree of difficulty of PS II is comparable to the material in a high school chemistry or physics course. The combination of IPS and PS II is a good physical science background for biology, and is a more unified program than IPS followed by a year of chemistry."

A reply card was enclosed, which had the following choices:

Will accept IPS and PS II
Will not accept IPS and PS II
Will consider on an individual basis
Wish to have more information.

Since Dana Hall is a girls' school, this mailing was sent only to women's colleges and coeducational institutions. The response showed that the following colleges will accept IPS and PS II as fulfilling the science admission requirement, or in some cases counting as one science course when two are required:

Barnard	Lawrence U.
Beaver	Macalester
Briar Cliff	Marymount
Bryn Mawr	Massachusetts U.
Carleton	Miami U. (Ohio)
Cazenovia	Middlebury
Cedar Crest	Millikin
Centenary	Mills
Chapman	Mount Vernon
Chatham	New College
Colorado College	New Hampshire U.
Colorado U.	New Rochelle
Connecticut College	New York U.
Denison	North Carolina
Duke	Oberlin
Emory	Ohio Wesleyan
Goucher	Pennsylvania U.
Grinnell	Pittsburgh U.
Hollins	Pomona
Hood	Radcliffe
Kirkland	Ripon
Knox	Rochester U.

*This does not mean that we recommend only IPS and PS II; the Dana Hall School recommends that a student take one physical science and one biological science. Ideally, the non-science student will take IPS in 8th or 9th grade, PS II in 9th or 10th grade, and biology in 11th or 12th grade.

Rockford	Vassar
St. Lawrence	Vermont U.
Scripps	Washington U. (Mo.)
Smith	Wellesley
Southern California U.	Western College
Syracuse U. (Buffalo)	Wisconsin U.
Temple Buell	Wooster

The following colleges will consider on an individual basis:

American U.	Finch
Antioch	Hartwick
Beloit	Jackson
Bradford Junior	Lake Forest
Colby Junior	Marietta
DePauw	Mary Baldwin
Dickinson	Skidmore
Elmira	Wilson
Endicott	

Will accept IPS and PS II except for engineering programs:

Boston U.	Denver U.
Cornell	Syracuse U.
Carnegie Mellon	

Will not accept IPS and PS II:

Northwestern	Rollins
Pine Manor	Sweet Briar

Desire more information:

Colby	Manhattanville

Favorable letters but no commitment:

Chicago U.	Michigan U.
Connecticut U.	Mount Holyoke

As yet we have no experience with students presenting IPS and PS II for admission. We anticipate this situation in the next several years, and in view of the positive response to our questionnaire we plan to introduce PS II into our curriculum.

How Do Students Respond to PS II?

By HAROLD PRATT
Science Coordinator
Jefferson County Public Schools (Colorado)

Why PS II? Where does it belong in our science curriculum sequence? Do we need this course? These are the questions most often asked by school administrators and science teachers when the PS II course is described to them. Contrast this reaction with the response of the eighth-graders in two schools in Jefferson County where PS II was offered for the first time during the 1967-68 school year as a part of the pilot program. In these two schools about 50 per cent of the students who had taken IPS in the eighth grade indicated that they would prefer to take PS II in grade nine, instead of the earth science course (ESCP) normally offered in that grade.

In one school, Creighton Junior High, Don Osse, the IPS instructor, selected a group of thirty students for the class he and I were to teach jointly. Fifteen of the students were boys and fifteen were girls. It soon became apparent that most of the students had requested PS II because of an interest in physical science that had been generated in the IPS class. It was also obvious that one or two were in the class because they considered more physical science to be less objectionable than earth science.

After a quick, one-day review of IPS Chapters 5 and 6, we started in earnest with Chapter 7. About one-third of the class had finished Chapter 8 the previous year, but the others had ended the year at various points in the course from the end of Chapter 6 to the middle of Chapter 8. This was the result of the students having come from the many different classes of three IPS teachers. This is one of the first articulation problems that must be worked out in an IPS-PS II sequence.

Nine weeks later we were ready to begin Chapter 12. Some teachers might rush impatiently through this material to get on with the "new" course. But the new course begins almost anywhere you please after Chapter 8. One strong reason for undertaking a second year of physical science is that one year does not provide adequate time to study many important topics carefully. For a majority of classes, some of the time will be used to complete chapters of the IPS course.

Except for the change in books, the switch to PS II was like starting any other new chapter. The style and the logical "story line" continued as they had in IPS. As we proceeded through the new material, it soon became obvious that while it was very revolutionary to us as instructors, it was no more strange to the students than many of the more standard experiments of IPS, such as melting point, density, etc. Their minds were not cluttered or distracted with standard experiments and concept development, as is the mind of the teacher trained in traditional experiments. This makes the preparation of the teacher an absolute must in the implementation of PS II. The experiments themselves are unique, and the reasoning is so different from any existing course that teachers need an opportunity to become acquainted with this new material. (How many teachers have measured the missing energy in the electrolysis of water, or in a weight-lifting motor?) Many times we found ourselves wondering about the purpose of an experiment or puzzled about the reasoning involved in a series of experiments.

The effect of IPS on the students was easily observed. The change in them provided a satisfying contrast when we considered what the same students had been a year earlier. They now displayed a marked improvement in their ability to set up an experiment and proceed with a minimum of instructions. From the beginning of the year, they were able to graph the results of an experiment with ease. Data would be recorded in their notebooks without specific instruction, and the students seemed to have more confidence in working the end-of-chapter problems than they did the year before.

In both the Jefferson County pilot schools, it was observed that the boys seemed to have an advantage over the girls in working with the equipment and, in general, comprehending the ideas involved. There appeared to be a difference here that was not present in the first year of IPS. I think part of the difference can be attributed to the kinds of apparatus and ideas with which we were dealing. The IPS course tends to be one in which the student heats, pours, and mixes things in test tubes, beakers, and evaporating dishes, while PS II tends more to connecting electric circuits, running electric motors, and spinning bicycle wheels. The boys' advantage may be partly attributed to a local curriculum sequence. All eighth-grade boys are required to take a technical-vocational course in which they spend a large portion of their time in various shop, mechanical, and electrical activities.

Our experience with PS II at this time does not provide a single simple answer to the question of where to place it in the science curriculum. The "why" of PS II has an easier answer. There are additional important topics in physical science to be studied beyond IPS, which many students are interested in and capable of studying without taking chemistry or physics.

Is our present senior high school sequence of biology, chemistry, and physics the best sequence? Would two years of physical science in the junior high school be an appropriate offering for some students? These questions seem as relevant as the question of where to use PS II. PS II places us in the happy, or frustrating, position of being able to question our present curriculum by having an alternative to present.

From its content and style, it seems clear that PS II can be useful both to those who later enroll in physics or chemistry and to those who do not. For those students who will not enroll in physics or chemistry, a good plan would be IPS in the ninth grade followed by PS II in the tenth grade. Biology would then be offered in the eleventh grade. For the future chemistry-physics students, IPS and PS II constitute an excellent eighth and ninth-grade sequence followed by the present high-school offerings. Other possible sequences could be suggested. Each would be designed to meet the needs of a particular student.

In the Classroom: Frustrations and Rewards

By THOMAS J. DILLON
Concord-Carlisle High School
Concord, Massachusetts

Continuing in the spirit of Introductory Physical Science, Physical Science II is a laboratory course that completely involves the student. Unlike the first-year course, however, where the teacher, by virtue of the material, plays a more passive role than is usually found in a science classroom, my experiences with PS II found me in a much more active role.

The reason for this is twofold. Perhaps most important is that I worked with a group of low-ability students. Even though they had completed a year of IPS, their mathematical sophistication and intellectual attitude were not always compatible with the demands of the course. Secondly, I suspect that even for average and above-average students the demands of the program are such that more teacher direction is needed than was the case with IPS. This is not to be construed as a deficiency. Indeed, the ideas in this program, although a bit more abstract than those in the first-year course, are nevertheless fundamental ideas. Rather than gloss over these abstractions, (as we did in the old days with our chalk-board diagrams of atoms, for example) the modern curriculum addresses itself to this very problem by making the abstractions as palatable as possible.

At least with my low-ability students, this active role I played can be partially justified when one considers the concepts involved. Where they were used to "nice" numbers and units, like 30 mi/hr, for example, they were now asked to manipulate and digest quantities like 1.60×10^{-19} amp-sec/atom of hydrogen. This kind of material can hardly be self-taught. It takes quite a bit of "chalk talk" to make students realize that although the names and numbers of the players may be different, the game is the same. In some cases it took the whole year for the student to realize this and to gain confidence in his ability to make the mathematics his servant and not his master. In a few cases, this reward was never to come.

The rewards, however, far outweigh the frustrations. It is not difficult to excite kids when you impress them with the fact that in their laboratory work they will count atoms. (How can you count things you can't even see?) It is not difficult to excite kids when in an overview of the course you point out that there is an intimate relationship between the heating of a beaker of water in the first chapter and spinning a bicycle wheel in a later chapter. (Ridiculous!) It is not difficult to excite kids when the very nature of the laboratory work requires experimental techniques and sophisticated data analyses that provoke a spirit of competition. (It was even exciting to me to hear an occasional muffled cheer as individual team data were posted for class analysis.) In short, the students responded very favorably to the laboratory situation. Even those who had difficulty with the mathematical analysis of the data saw a purpose in what they were doing. They enjoyed the "detective story" atmosphere that was built into the lab program. (Where is the missing heat? Is the energy all accounted for?) Like the IPS, this course has a story line that is soon spotted by the students. They have to work very hard, and often harder than they would like, to appreciate this point, but for those who can stick it out, the rewards are ample.

In conjunction with IPS, this course forms an excellent two-year sequence in physical science. Unquestionably it is a first-class preparation for chemistry and physics. For students who may not be science-oriented and probably would not go on to chemistry and physics, the program also has obvious merit. This two-year sequence in physical science, followed by a year of biology, would comprise a very good science program for them. In any event, regardless of the level of the students, the teacher who has been swept up by the spirit of the new science offerings at all levels can be assured that Physical Science II will hold its own with any of them as a program that promises ten busy fingers with a purpose.